Sequence of TRIZ Tools Application

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Abstract

TRIZ comprises a lot of tools. Accordingly, it is difficult for a TRIZ beginner to select an appropriate tool, a group of tools, or the order of their application when working on a project.

This paper makes an attempt to recommend in what sequence various TRIZ tools should be applied when solving the following types of problems:

- Adapting a system to a new use.
- Improving an existing system.
- Synthesizing a new system.
- Forecasting system evolution.

Key words:

TRIZ tools, problem types, types of innovative projects, TRIZ tools application sequence.

1. Review of Publications

The use of different TRIZ tools and the sequence of their application were first outlined by G.Altshuller in different ARIZ modifications [1-8]. New TRIZ tools were introduced into each subsequent ARIZ modification [9].

The TechOptimizer [10] and IWB [11] software packages offer an opportunity to apply various TRIZ tools. GEN 3 Partners, Inc. [12] has developed a roadmap describing the application sequence for various TRIZ tools. This methodology has been described to the fullest extent in [13].

The author of the paper initially presented options of TRIZ tools application for performing search, selecting and solving problems, as well as forecasting the evolution of engineering systems in 1976 in [14-15], and later in [16-18]. The whole methodology was named "system analysis". By that time, TRIZ comprised the following tools: ARIZ-75, 40 inventive principles for resolving technical contradictions, 10 additional inventive principles, paired inventive principles (principle antiprinciple), Su-field analysis, 10 standards, and physical effects. This methodology combined the above tools and was supplemented with existing system analysis and new system synthesis. The methodology described the sequence of TRIZ tools application for existing system analysis, new system synthesis, system evolution forecasting, and standard inventive problem solving. The author paid much attention to the analysis of existing systems and building of hierarchical structure of a system.

Interactions among individual system elements and between the system and its super-system and the environment were also investigated using an interaction matrix. Types of interactions and effects were determined at the next stage. The analysis resulted in revealing preliminary problems. In this aspect, the methodology can be considered as a kind of run-up to structural functional analysis. Besides, the methodology described a way to create new systems from a system approach perspective. Trees of targets, needs, functions, system integration principles, optional techniques for building a system and its elements were drawn up. A morphological matrix was created at each level. The options were selected in the direction from the upper level (tree of targets) to the lower one. Hence, the lower level tree was drawn up only for a specific selected option. The selection was performed by chosen experts using the method of paired comparisons. Following the emergence of new TRIZ tools, the author of the paper made an attempt to expand the methodology of TRIZ tools application for different functions. This methodology was described in [14-19], and the results of its usage were given in [20-21]. The author of the paper taught the System Analysis course at the Institution of Advanced Training of Shipbuilding Industry (IPK SP) in 1976-1990 and at People's University of Scientific and Technical Creativity (UNNTT) affiliated to the Vyborg Palace of Culture in Leningrad.

By 1974, the author had developed the methodology of applying existing systems for new purposes [22], which was published in [23-24]. The development of this methodology was fueled by the collection of new use invention certificates that the author of the paper has been collecting since 1973. The author classified the resources and developed the sequence of their identification and application. By that time, the author has realized that the resources can encompass a large class of material objects (substances, fields, parameters, etc.), as well as non-material ones like functions, information, knowledge. The parameters considered by the author include all technical parameters, including physical and geometrical, economic, ergonomic, aesthetic, and psychological ones.

The methodology of TRIZ tools application was continuously improved by the author [25-26].

All these efforts made the use of TRIZ tools by a TRIZ beginner much easier. Presently, however, there is no unified vision as to what tools should be used to solve different types of problems and perform different projects, and in what sequence.

This paper makes an attempt to further improve this methodology. The use of specific tools and the sequence of their application for different types of projects will be further discussed.

2. TRIZ Functions and Structure

The functions and structure of TRIZ have been presented in [28] by the author. A slightly extended version follows:

2.1. TRIZ Functions

Major TRIZ functions include:

1. New system synthesis.
   1.1. New generation system synthesis.
   1.2. Radically new system synthesis.
2. Existing system improvement.
   2.1. Elimination of disadvantages.
   2.2. Functionality improvement.
   2.3. Cost reduction.
3. New use of existing system.
   3.1. Extension of existing system use.
   3.2. Search for new use of existing system.
4. Problem search.
5. IP strategy formulation.
6. Creativity development.
   6.1. Creative (inventive) thinking development.
   6.2. Creative personality development.
   6.3. Creative community development.

2.2. TRIZ Structure

Major TRIZ components:

1. Laws of system evolution.
   1.1. Laws of engineering system evolution.
   1.2. Laws of evolution of needs.
   1.3. Laws of function change.
2. ARIZ.
3. Su-field analysis.
4. TRIZ knowledge base.
   4.1. Standards.
   4.2. Effects.
   4.3. Inventive Principles.
   4.4. Resources.
5. Anticipatory failure analysis.
6. System oriented analysis and synthesis.
   6.1. Analysis and synthesis of needs.
   6.2. Analysis and synthesis of functions.
   6.3. Analysis and synthesis of action principles.
   6.4. Analysis and synthesis of systems.
7. Cause-and-effect analysis.
8. Value analysis.
9. IP strategy formulation methodology.
10. Creative (inventive) thinking development methods.
    10.1. Systemic thinking.

10.2. Evolutionary thinking.
10.3. Contradiction thinking.
10.4. Resource thinking.
10.5. Modeling.
10.6. Creative imagination development.

11. Theory of creative personality development.
12. Theory of creative community development.

All TRIZ sections can be roughly divided into two parts: methods for problem solving and methods for creative skills development. Methods for problem solving include 1-9, and those for creativity development comprise 10-12. In line with this classification, the structural TRIZ diagram can be drawn up as shown in Fig.1.

Problem Solving	Creative Skills Development
Laws of Systems Evolution.	
ARIZ.	
Su-Field Analysis	Methods of Creative Thinking Development
Knowledge Base. – *Standards.* – *Effects.* – *System of Inventive Principles.* – *Resources.*	Theory of Creative Personality Development
Anticipatory Failure Determination	
System Oriented Analysis and Synthesis. – *System and Function Analysis.* – *Analysis and Synthesis of Needs.* – *System Synthesis.*	Theory of Creative Community Development
Cause and Effect Analysis.	
Value Analysis.	
IP Strategy.	

Fig. 1. TRIZ Structural Diagram

2.3. Use of TRIZ tools

Specific tools correspond to every TRIZ function. Some tools are used to perform several functions. The author of the paper has drawn up a table showing TRIZ tools application for specific functions in [28]. An extended version of this table is given below (see Fig. 1). The author has considered only some of the functions and tools of the state-of-the-art TRIZ that are the most important in his opinion.

Table 1. TRIZ Function and Structure

Functions		Structure															*Function value*
							Knowledge base							Development of creative			
								Effects									
		Laws of engineering system evolution	ARIZ	Su-field analysis	Anticipatory Failure Analysis	System oriented analysis and synthesis	Standards	Physical	Chemical	Biological	Mathematical	Techniques	Resources	thinking	personality	community	
1	Forecasting of engineering system evolution	10	1	7	7	10	8	2	2	2	2	6	8	8	1	1	**75**
2	New system synthesis	10	1	6	7	10	8	2	2	2	2	9	2	10	1	1	**73**
3	Existing system improvement	10	10	9	5	10	9	8	8	8	8	9	10	10	1	1	**116**
4	Problem search	10	1	7	9	9	9	6	6	6	6	6	7	10	1	1	**94**
5	Problem selection	10	10	1	5	9	8	2	2	2	2	2	5	9	1	1	**71**
6	Problem solving	7	10	8	9	7	9	8	8	8	8	8	8	10	1	1	**110**
7	Solution evaluation	10	7	7	7	8	9	2	2	2	2	2	5	10	1	1	**75**
8	Creative thinking development	10	10	9	5	1	2	2	2	2	2	3	5	10	1	1	**65**
9	Creative personality development	7	6	2	2	6	1	1	1	1	1	1	4	9	10	1	**64**
10	Creative community development	7	4	3	5	6	1	0	0	0	0	4	7	8	5	10	**60**
***Tool** value*		**91**	**61**	**59**	**64**	**76**	**65**	**31**	**31**	**31**	**31**	**53**	**59**	**94**	**23**	**19**	

Note. Numbers in the table indicate the value of the tool applied for the given function. Maximum value is 10, minimum value is 0. The evaluation was made by the author acting as a consultant for engineering projects.

By author's assessment (see Table 1), the values of TRIZ functions and tools are distributed as follows (see Table 2 and 3):

Table 2. Value of TRIZ Functions

Rank	Function	
	Name	*Value*
1.	Existing system improvement	116
2.	Problem solving	110
3.	Problem search	94
4.	Forecasting of engineering system evolution	75
5.	Solution evaluation	75
6.	New system synthesis	73
7.	Problem selection	71
8.	Creative thinking development	65
9.	Creative personality development	64
10.	Creative community development	60

Table 3. Value of TRIZ Tools

Rank	Tool	
	Name	*Value*
1.	Creative thinking development	94
2.	Laws of engineering system evolution	91
3.	System oriented analysis and synthesis	76
4.	Inventive problem solving standards	65
5.	Resources	64
6.	Anticipatory Failure Analysis	64
7.	ARIZ	61
8.	Su-field analysis	59
9.	Techniques	55
10.	Effects	33
11.	Theory of creative personality development	23
12.	Theory of creative community development	19

Table 1 shows which tools should be used primarily for each of the functions.

Tables 2 and 3 show which functions are the most important for innovative projects and which tools should be perfected first of all.

Similar tables can be drawn up for all TRIZ functions and tools. The value of the functions and tools should be assessed by leading experts. A statistic processing of the data can lay a foundation for compiling more objective training programs for specialists in innovative projects.

Similar efforts can be made in relation to other TRIZ directions.

3. Sequence of TRIZ Tools Application

As a rule, performing the above functions and accomplishing innovative projects requires the use of several TRIZ tools. In this case the order the tools are applied in becomes important. Each function may require a different sequence. The author has produced specific recommendations in this regard. Some of them are mentioned below.

3.1. New Use of Existing System

One of the innovative projects types is focused on finding a new application for an existing system. For this purpose, the author developed a new methodology in 1974, which was published in [15]. The methodology is based on leveraging the use of system resources.

First, all system resources must be revealed, and then ways to utilize them are identified.

The author considers the following types of resources:

1. Functions.
2. Elements.
3. Interactions among elements.
4. Shape.
5. Energy.
6. Information.
7. Substance.
8. Field.
9. Flows.
   - 9.1.1. Substance flows.
   - 9.1.2. Energy flows.
   - 9.1.3. Information flows.
10. Space.
11. Time.
12. Processes.
13. Parameters.
14. System resources.

The resources can belong to the *operational zone, subsystems, system proper, supersystem and the environment*. They can be used "as is" or can be modified.

The sequence in which the revealed properties should be applied in line with a new use can be as follows:

1. The use of the system as a whole.
   1.1. The use of main properties, functions, actions as a whole
   1.2. The application of additional properties, functions, actions as main ones.
   1.3. The application of redundant or harmful properties, functions, actions as useful ones.
   1.4. The use of properties, functions, actions that oppose those revealed.
2. The use of subsystems (similarly to point 1).
3. The use of substances and fields belonging to subsystems.
   3.1. The use of substance and field properties that act as main in regard to the system and its subsystems.
   3.2. The application of substances and field properties that are auxiliary in regard to the system as main ones.
   3.3. The application of substances and fields that are redundant in regard to the system as useful ones.
   3.4. The application of substances and fields that are harmful in regard to the system as useful ones.
4. The use of substance microstructure of a subsystem.
   4.1. The use of main properties of microstructure: molecules, atoms, elementary particles, etc.
   4.2. The use of microstructure properties that act as auxiliary in regard to the system.
   4.3. The application of microstructure properties that are redundant in regard to the system as useful ones.
   4.4. The application of microstructure properties that are harmful in regard to the system as useful ones.

The details of applying some newly revealed resources can be worked out as a result of brainstorming involving experts from diverse domains. Besides, any functional classification available, for instance, the one provided by the US Patent and Trademark Office, can be used to discover new system applications. As of today, a number of recommendations on how to use individual properties are available. An application roadmap for properties and functions should be drawn up next. A special attention should be paid to obtaining system effects produced by new combinations of elements and processes by making use of another system, supersystem, environment, etc.

This methodology has been taught since 1975, and was repeatedly used in practice. Here is one example:

A company published fairy tales on CDs, which enabled watching, listening, and reading the tales in five languages. The company decided to raise its profits without making significant investments.

After the available resources were analyzed, it was suggested that the product be used as a means for simultaneous learning of five foreign languages. The product only needed to be supplemented with a vocabulary and learner manual.
Eventually, the selling price of the product has jumped 10-fold.

3.2. Algorithm of TRIZ Tools Application for Synthesizing New Systems and Improving Existing Ones

Algorithms of TRIZ tools application for problem solving and forecasting have been presented by the author in [25-26].

A simplified sequence of TRIZ tools application for synthesizing new systems and improving existing ones is shown in Fig.2.

This algorithm can be described as follows:

1. Existing system improvement.
    - 1.1. Correction of disadvantages.
        - 1.1.1. If the problem has been stated, the following is applied.
            - 1.1.1.1. Su-field analysis or resolving of contradictions.
            - 1.1.1.2. Su-field analysis.
                - 1.1.1.2.1. If a solution has been generated as a result of Su-field analysis, the process ends.
                - 1.1.1.2.2. If no solution has been obtained, the knowledge base is referred to.
            - 1.1.1.3. Resolving of contradictions.
                - 1.1.1.3.1. If the contradiction type has been stated, the knowledge base is referred to.
                - 1.1.1.3.2. If the contradiction type has not been stated, ARIZ is applied.
        - 1.1.2. If the problem has not been stated, the following is applied.
            - 1.1.2.1. System oriented analysis with possible supplements represented by cause-and-effect analysis, anticipated failure analysis and value analysis.
            - 1.1.2.2. Trimming is recommended after the analysis has been completed.
            - 1.1.2.3. If a solution has been generated, the process ends.
            - 1.1.2.4. If no solution has been obtained, pass over to 1.1.1.3.
2. Synthesizing a new system.
    - 2.1. Synthesizing a system of new generation.

As a rule, changes occur at system level, less often at level of operation principle. In this case, forecasting methods [29, 34, 39, 41] and laws of engineering system evolution [30-33, 35-38, 40, 42, 43] should be applied.

2.2. Synthesizing a fundamentally new system.

- 2.2.1. Application of system oriented synthesis [25] and [26].
  - 2.2.1.1. *Constructing a model of needs*. Application of methods to reveal hidden needs and forecasting of future needs [35-37].
  - 2.2.1.2. Constructing a functional model [25, 26, 38, 42].
  - 2.2.1.3. Constructing an operation principle model [43, 44].
  - 2.2.1.4. *Constructing a system model.* The forecasting methodology [43] and laws of engineering system evolution [43] are used for constructing the model.
- 2.2.2. Forecast verification.
- 2.2.3. Improving the obtained system – see item 1.

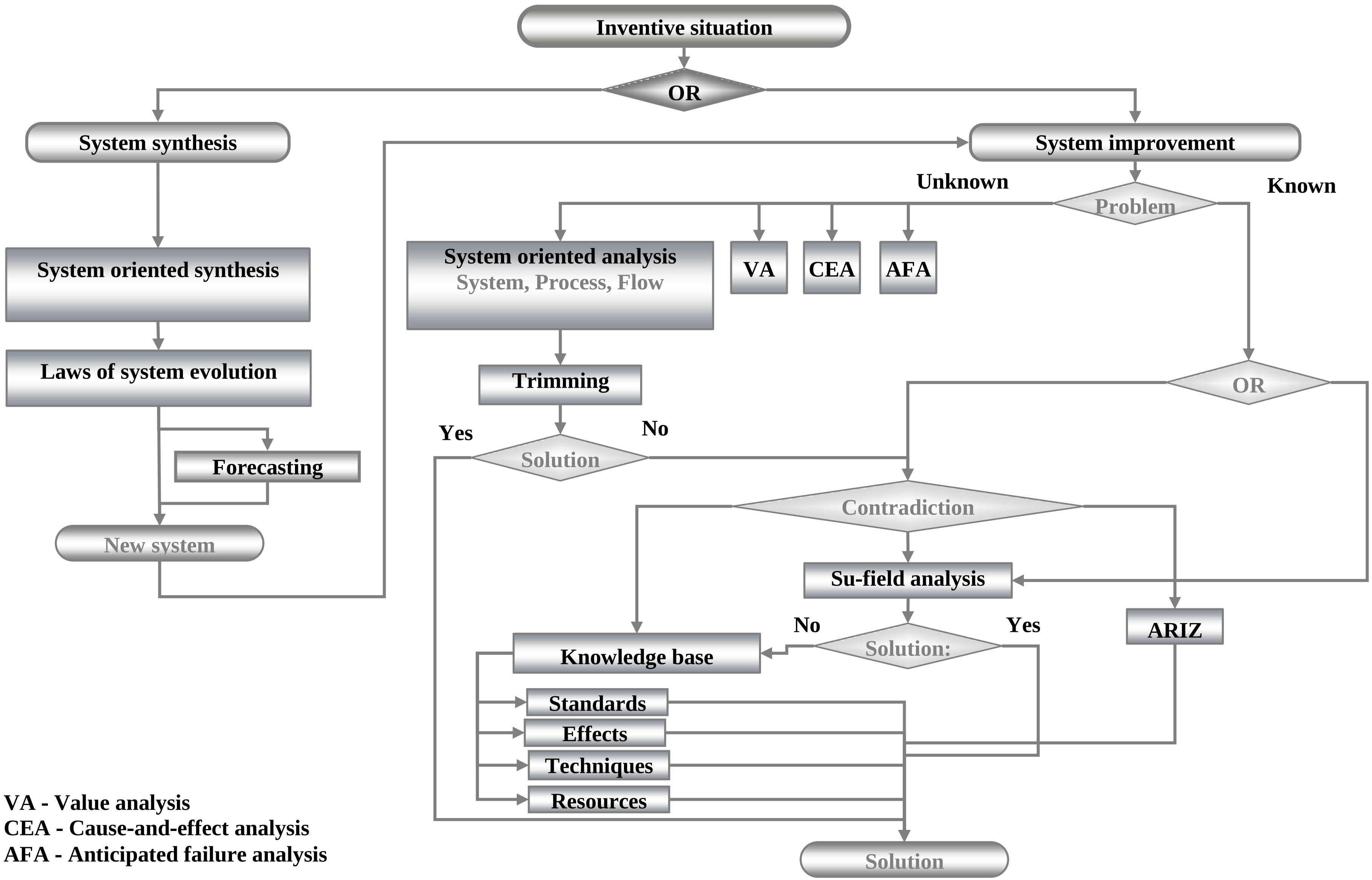

Fig. 2. Algorithm of TRIZ Tools Selection for Synthesizing New and Improving Existing Systems.

4. Forecasting Technology

The forecasting process can be either concise (*express forecasting*), or detailed (*in-depth forecasting*).

Express forecasting is performed primarily through the use of ***system of standards*** [8] for inventive problem solving, **system of generalized models** [27], and ***laws of engineering system evolution*** [43]. The algorithm of express forecasting has been described by the author in [24, 43].

The in-depth forecasting is performed as follows:

1. System evolution analysis.
2. Forecast of evolution of needs.
3. Functional model synthesis.
4. Information search.
5. Disclosing the evolution trends of the system under investigation.
6. Disclosing the evolution trends of alternative systems that perform the same function.
7. Disclosing the evolution trends of systems that perform an opposite function.
8. Disclosing the general evolution trends of the system that performs the main function of the system under consideration.
9. Disclosing the contradictions of system evolution in accordance with items 5-8.
10. Elimination of contradictions.
11. General evolution forecasting for the investigated system.
12. Forecast verification.

As a rule, forecasting starts with the analysis of the system under investigation. The analysis is performed using S-curve and laws of system evolution in line with the method described in [43]. At this stage, the evolution level of the system is identified with the purpose to decide whether the system under investigation should be further developed, or a new generation system should be synthesized. System development resources are also disclosed.

The next stage consists of forecasting the evolution of needs in line with the special method based on the laws of evolution of needs [35-37, 43].

Next, a functional model that satisfies the needs disclosed is constructed using the method described in [38, 43].

The information is searched for based on *objective*, *functional*, and *semantic attributes* [43, 48]. Evolution trends of the system under investigation, trends of system evolution along the main function line, and trends of system evolution along the inverse function line are arranged based on the obtained information. At first, the information is arranged in *historical* order, and then in *logical* and *logical-and-historical* orders. If necessary, the trends of system evolution along the *auxiliary function* lines are identified using the same procedure.

The methodology for identifying the evolution trends of specific systems is presented in [43]. Next, the resulting trends are compared to those obtained through the use of the system of trends described by the author in [43].

The forecasting process may yield solutions that contradict each other. Such contradictions are eliminated using TRIZ tools as described in [43]. As a result, a general forecast of system evolution is made.

The final stage consists of **forecast verification**.

To verify the model in the course of system design, special simulation computer programs are often used. Such simulation programs are strictly customized, e.g. for IC modeling only. Anticipated failure analysis [50] is a universal means of verification.

The author has repeatedly tested the forecasting methodology in various projects aimed at forecasting the evolution of different engineering systems.

The first in-depth analysis was made for the shielded metal-arc welding technology at the All-Union Research Institute of Electric Welding Equipment (VNIIESO) in Leningrad in 1982. About 80,000 patents and invention certificates were analyzed. As a result, patent applications were filed and the solutions were embedded into the next generation equipment [46]. Later on, the author performed forecasting for other types of welding [47, 49]. Many times the author conducted an express forecasting for different engineering systems for world's leading companies, including Samsung, Intel, BOSCH, CompAir, Dietz-Motoren, Krupp Uhde, Philips Semiconductors, Karat Digital Press, HP, Applied Materials, etc.

The author gave a course of lectures on forecasting of engineering system evolution at the Institution of Advanced Training of Shipbuilding Industry (IPK SP) in 1976-1990 and for second year students at People's University of Scientific and Technical Creativity (UNNTT).

The forecasting algorithm [39, 43] is given in Fig. 3.

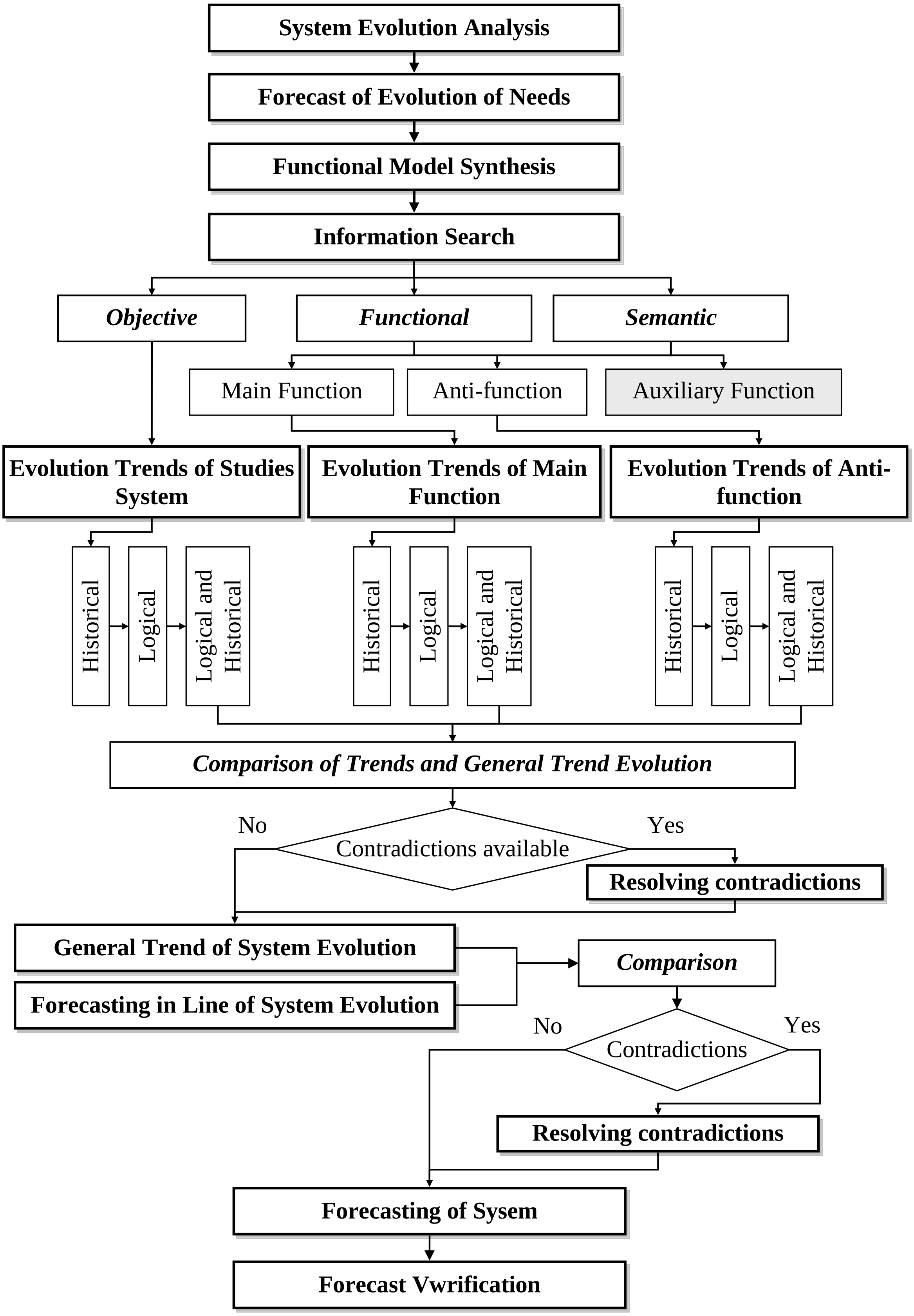

Fig. 3. In-depth Forecasting Algorithm

5. Conclusion

The paper dwells on the structure and main functions of TRIZ, shows which TRIZ tools are preferable for applying to perform a specific function, as well as what sequence these tools should be applied in for carrying out projects of such types as:

- New use of existing systems.
- Improving existing systems.
- New system synthesizing.
- System evolution forecasting.

It is the author's opinion that the value of the whole range of TRIZ functions and tools should be evaluated in future by analogy with Table 1 with the assistance of leading TRIZ experts.

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